Journal of Petroleum Science and Engineering 153 (2017) 385–390

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

Aquathermolysis of heavy oil using nano oxides of metals

Alfiya Lakhova[a], Sergey Petrov[a,b], Dina Ibragimova[a,b], Galina Kayukova[b,c], Aliya Safiulina[a,*], Alexey Shinkarev[c], Rachael Okekwe[a]

[a] Kazan National Research Technological University, Karl Marx St., 68, 420015 Kazan, Russia
[b] Kazan Federal University, Kremlevskaya str., 18, 420008 Kazan, Russia
[c] A.E. Arbuzov Institute of Organic and Physical Chemistry, Kazan Scientific Center, Russian Academy of Sciences, Arbuzov st., 8, 420088 Kazan, Russia

ARTICLE INFO

Keywords:
Homogeneous catalysis
High-viscosity oil
Nano-sized particles
Iron oxides
The component composition of oil
Rheological curve

ABSTRACT

The effect of suspended nanoparticles of magnetite and hematite on thermal decomposition of heavy oil at a temperature of 360 °C in a vapor medium at different system pressures is revealed. The preferential destruction reactions of macromolecular components of oil, which lead to the reduction of oil viscosity, are established. The effect of zinc and aluminum oxides as additives initiating cracking of hydrocarbon bonds is studied. The changes in structure of the component of the converted products, as compared to the original crude oil, are obtained. Conducting the process in the presence of additives at a pressure of 11 MPa led to the reduction of the aromaticity of the final products, increase in the yield of hydrocarbon oils and the formation of gaseous products. It is observed that the amount of asphalt-resinous substances is reduced as the result of their conversion in the presence of additives. Rheological curves of conversion products are obtained, based on them the peculiarities of viscosity-temperature characteristics change can be shown.

1. Introduction

In modern refineries, the proportion of heavy oil in total volume increases every year. It is reported by the International Energy Agency that the worldwide resources of heavy oil are around 6 trillion barrels, which are mainly located in Canada, Venezuela, Russia and the USA. A review on recent advances on non-catalytic and catalytic process technologies for upgrading of heavy oils and residues is given in the article (Ancheyta et al., 2007). Therefore, there is a crucial need for new upgrading technologies that would provide them with a cost-effective development based on an efficient process technology and enhancement of catalytic systems. Catalytic performance can be improved by the use of various transition metal precursors, additives, preparation techniques, use of other non-conventional metals, new active phases (carbides, nitrides etc.) and promoters, modifying of supports (Sahu et al., 2015). As many authors have noted (Sahu et al., 2015; Zhang et al., 2007; Angeles et al., 2014), the development of catalytic systems has undergone two main stages: heterogeneous solid phase-stage and homogeneous dispersed phase-stage.

The homogeneous dispersed catalysts are divided into water-soluble (Mo, Ni oxide with aqueous ammonia of Chevron Inc.; Mo, V and Fe metal oxide or salt and heteropoly acid of UOP Co.; Ni, Fe, Mo and Fe-Co liquid catalyst of Petro China Company Limited; Phosphomolybdic acid ammonium heptamolybdate molybdenum oxalate of Exxon Research and Engineering Co. etc.), and oil-soluble (Mo or W salts of fatty acids of Chevron Inc.;CrO_3tert-butyl alcohol, Molybdenum alicyclic or naphthenate, Fe_2O_3 and Mo naphthenate of Exxon Research and Engineering Co.; Iron pentacarbonyl or molybdenum 2-ethylhexanoate of Alberta Oil Sands Technology and Research Authority etc.) (Sahu et al., 2015).

One of the key and promising areas is in using nano-scale catalysts. They have significant advantages, namely large surface area in the absence of the porous structure, which could be plugged with coke, high stability of activity and the elimination of diffusion control in the heavy oil feedstock. In the article by Canadian scientists the catalytic activity of micro particles and nanoparticles of nickel in the thermolysis reactions of Athabasca oil is compared. The authors found a significant reduction in viscosity of the converted products with nano-sized particles, apparently due to greater catalytic surface area (Hashemi et al., 2013). It was proposed that nano-nickel catalyst in the aquathermolysis of extra-heavy oil San56-13-19 accelerated the pyrolysis of asphaltene, which led to the production of O-containing substances and, therefore to the reduction of viscosity up to 90.36% (Wu et al., 2016). Hydrocracking of heavy residue in the presence of dispersed colloidal catalyst (nanosheet-structured WS_2) was compared with those of bulk WS_2 and MoS_2. The single-layer WS_2 catalyst provided high yield of fuel (45.4 wt%) and asphaltene conversion (75.3 wt%) (Gul et al., 2014).

* Corresponding author.
E-mail addresses: lfm59@mail.ru (A. Lakhova), psergeim@rambler.ru (S. Petrov), kayukova@iopc.ru (G. Kayukova), aliyahanova@mail.ru (A. Safiulina).

http://dx.doi.org/10.1016/j.petrol.2017.02.015
Received 25 July 2016; Received in revised form 7 February 2017; Accepted 22 February 2017
Available online 28 February 2017
0920-4105/